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GB A 2133927 GB A 2039146 GB A 2017138

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Selected US specifications from IPC sub-class H05B

(54) High contrast electroluminescent displays

(57) A d.c. or a.c. electroluminescent panel 1 comprises a transparent substrate 3, a transparent first electrode film 2, a thin film phosphor layer 4, a black or dark powder back layer of electrically conductive material 5, and a second electrode film 6. Application of a voltage across the phosphor layer causes it to emit light. In this invention, the black powder back-layer significantly enhances the contrast of the panel. The black powder of the back layer 5 may be a metal chalcogenide a metal oxide or a metal sulphide.

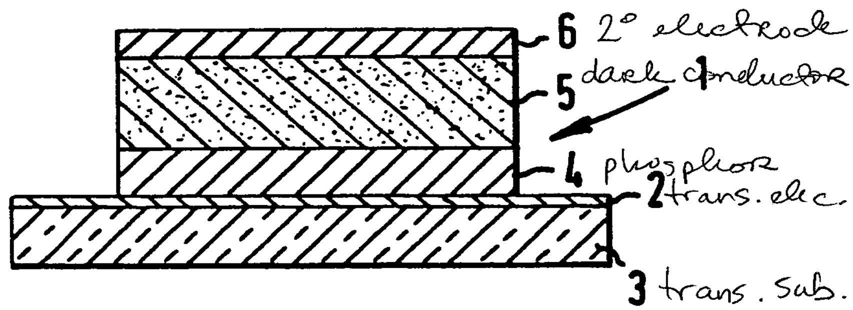

FIG.1

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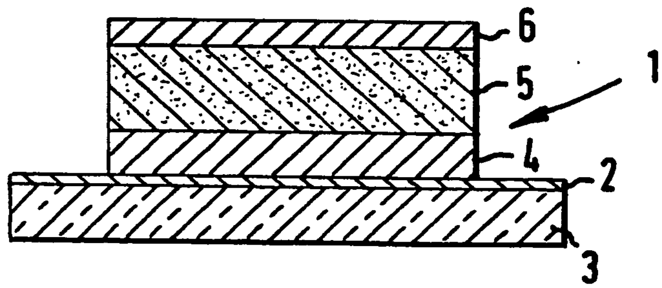

FIG.1

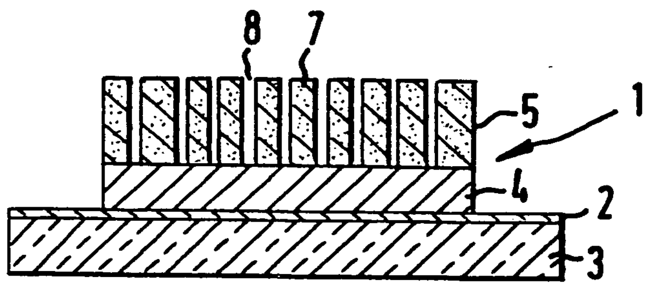

FIG.2

SPECIFICATION

High contrast electroluminescent displays

This invention relates to electroluminescent (EL) phosphor panels and displays designed for both unidirectional and alternating voltage operation, (DCEL) or (ACEL).

Thick film powder DCEL panels which are also capable of ACEL operation are conventionally manufactured by a process comprising the steps of:

(a) depositing a transparent front electrode film e.g. of tin oxide, onto a transparent insulating substrate, e.g. glass;

(b) spreading an active layer, comprising phosphor particles, such as zinc sulphide (ZnS) doped with an activator such as manganese (Mn) and coated with copper suspended in a binder medium, on the front electrode; this layer is typically 10–50 μm thick (hence 'thick film' device);

(c) depositing a back electrode film, e.g. of aluminium on the active layer;

(d) applying a unidirectional voltage to the electrode films for a predetermined time, so that in the region of the positively biased front electrode the copper coating is stripped from phosphor particles to form a high resistivity, high light output layer, typically 1–2 μm thick. The relatively thick layer of unstripped phosphor particles then remaining behind this thin light-emitting layer constitutes a highly conductive control layer.

The last step, (d) in the manufacturing process, is known as 'forming' and is more particularly described in U.K. Patent No. 1,300,548. The electrodes can of course be laid down in any desired shape to produce a particular display, e.g. if the electrodes comprise mutually perpendicular strips a matrix of active phosphor elements or 'dots' will be defined each of which may be addressed and driven using conventional electronic techniques to form alpha-numeric characters. Having such a process we have designed and built a 2000 character DCEL panel suitable for use with a computer as a monitor display and replacing the conventional bulky cathode ray tube monitor display.

A disadvantage of the all-powder panels is that the display elements can presently only produce a light output which, whilst acceptable in all but the highest ambient light conditions, is difficult to maintain throughout the life of the display. Moreover, since the quiescent colour of the phosphor material is a very light shade of grey such high light output levels are required to provide an adequate display contrast.

The powder panels described above are known as 'self-healing', i.e. the copper-coated powder backlayer, the control layer, protects the thin, high resistance, light-emitting 'formed' layer from catastrophic breakdown due to excessive current density at defects or points of weakness by further copper stripping or 'forming' at such 'hot spots'.

To ensure a more reproducible manufacturing technique, not requiring the expensive and time-consuming forming operations, a composite thin film powder electroluminescent panel has been proposed (see 'A Composite ZnS Thin Film Powder Electroluminescent Panel' C.J. Alder et al, Displays, January 1980, at page 191). Such panels are in effect a hybrid structure in which a thin film, equivalent to the light-emitting formed layer in conventional DCEL panels, is coated with the copper-coated phosphor backlayer, i.e. control layer. The thin film is of semi-insulating activator-doped phosphor, such as ZnS doped with Mn, and is typically 200A to 1 μm thick. This light-emitting film is deposited onto the transparent front electrode of the panel by sputtering, evaporation, electrophoretic plating or any of the known ways of depositing thin films on substrates. The conventional control layer and the back electrode are spread and vacuum-deposited onto the light-emitting film in the known manner. The control layer need not contain Mn since the light emitted by the device originates from the thin film. U.S. Patent No. 4,137,481 describes such a hybrid panel which may or may not require the application of a forming current before it is ready for use. If a forming current is required, forming is found to occur at much lower current densities than those required for conventional thick film DCEL panels.

The hybrid DCEL panel is protected by the control layer from catastrophic breakdown due to excessive current density at defects and points of weakness by retaining its forming properties in the same way as the "thick film powder only" DCEL panels. However, the known hybrid panels using conventional control layers still suffer from the effects of further forming during extensive use, leading to brightness degradation with time. Again, the contrast provided by such known hybrid devices is poor.

It is an object of the present invention to provide a thin film powder composite EL (hybrid) panel with improved brightness maintenance during its operational lifetime and providing significant contrast enhancement.

It is a further object of the present invention to provide a thin film powder composite panel that is cheaper to manufacture than known powder DCEL panels.

The present invention is based on the realisation that materials other than phosphors have the property of controlling the current supplied to the first layer of activator-doped phosphor. Thus, the choice of materials that can be used for the control layer is much greater and materials can be selected for other advantageous properties that they possess. In particular in accordance with the pre-

sent invention, a material is chosen that has a dark hue, which means that the contrast of the panel will be greatly improved and its legibility will be greatly increased.

Phosphors necessarily have a relatively large bend gap or otherwise they would not be phosphorescent and this results in the phosphor having a grey colour. Thus, the present invention is distinguished from known art by using a material in the control layer that has a dark colour.

It is preferred that the material chosen form the dark control layer also is sufficiently electrically conductive to provide the necessary current flow to the panel without the use of further electrodes. This reduces the cost of providing the electrodes and hence reduces manufacturing costs.

In known panels suitable for multiplex addressing the two sets of electrodes are each composed of thin parallel strips of conductive material. The electrodes of one set extend perpendicularly to the electrodes of the other set and pixels are thus formed in the areas that are sandwiched between an electrode of each set.

The set of electrodes on the rear of the panel, i.e. on the side of the panel remote from the transparent substrate, have customarily been provided by vacuum-deposition of aluminium. However if an electrically conductive material is chosen for the conductive layer, the rear set of electrodes can be dispensed with if the control layer is formed in ridges running perpendicularly to the strips of the front transparent electrode film. This may be achieved by grooving or "scribing" a uniformly deposited control layer with a thin instrument, which is a much cheaper operation than depositing thin strips of aluminium electrodes on the back of the panel.

According to the present invention, an electroluminescent phosphor panel suitable for both unidirectional and/or alternating voltage operation, includes in serial order, a transparent electrically insulating substrate, a transparent first electrode film, a first layer of semi-insulating self-activated or activator doped phosphor, preferably with an average thickness less than 5 microns, and a second layer comprising an electrically conducting or semi-conducting dark-coloured powder selected e.g. from transition, rare earth or other compounds such as metal oxides, sulphides or other chalcogenides.

According to the present invention in another aspect thereof a method of manufacture of an electroluminescent phosphor panel suitable for both unidirectional and/or alternating voltage operation includes the steps of depositing a transparent first electrode film onto a transparent insulating substrate, depositing a first layer of semi-insulating self-activated or activator-doped phosphor not greater than 5 microns thick on to the first electrode film by thermal or electron beam evaporation techniques or by sputtering or by chemical deposition, spreading for example by spray painting techniques, a second layer of an electrically conducting dark coloured powder selected from transition, rare earth or other metal compounds such as oxides, sulphides, or other chalcogenides, on to the first layer and depositing a second electrode film onto the second layer.

Two embodiments of the invention will now be described by way of example and with reference to the accompanying drawings (Fig. 1) which are cross-sectional view of two EL panels.

Referring to Fig. 1, the panel indicated by reference numeral 1, includes a transparent tin oxide or indium tin oxide electrode 2 laid, for example, by sputtering on part of the upper surface of a glass substrate 3. The electrode 2 can be etched to any desired shape or pattern depending on the type of display required; for example, the display required may be a dot matrix display in which case the electrode 2 will take the form of a plurality of parallel strips of width and spacing determined by the desired 'dot' (pixel) size.

A semi-insulating thin film 4 of self-activated or activator-doped phosphor, not more than 5 microns thick, is deposited on the electrode 2. The film for example may be ZnS activated with Mn in which case the display will exhibit a yellow colour in operation. Alternative colours may be effected by using activators other than Mn in ZnS, and other lattices with Mn and activators such as rare earth metals. For example, other phosphor lattices which may also be used are the alkaline sulphides BaS, CaS and SrS, fluorides such as LaF_3 and YF_3 and oxides such as Y_2O_3 or any other suitable phosphor.

A powder control layer 5 is deposited on the thin film 4. The control layer is preferably black, but essentially dark in colour and is selected from transition metals, rare earth metal, or other metal compounds such as oxides, sulphides or other chalcogenides. It may for example, by PbS, PbO, CuO, MnO_2, Tb_4O_7, Eu_2O_3, PrO_2 or Ce_2S_3.

An aluminium electrode 6 is deposited, for example, by evaporation on to the control layer 5. This electrode can be mechanically scribed to provide a shape corresponding or relating to the electrode 2 to form the desired display pattern, for example if a dot matrix display is required the electrode 6 will take the form of a plurality of parallel strips mutually perpendicular to the strips of electrode 2 so that the 'intersections' of the two sets of strips define the display pixels.

Electrode 2 can be either positively or negatively biased. In operation a DC or AC voltage, typically between 20 and 200V, is applied across the electrodes 6 and 2. Light is emitted from the thin film 4, in a pattern deter-

mined by the electrode shape. The contrast between the light-emitting region of the thin film 4 and the non-light-emitting region is enhanced by using a black or dark powder control layer 5, so that the display may be read by an observer even in relatively high ambient light conditions and with display brightness of only a few foot-lamberts, typically 4—15 fL.

Two such panels have been built and tested and produced yellow and green displays respectively with good contrast enhancement. In the first, the thin film layer 4 comprised ZnS activated with Mn and in the second, the thin film layer 4 comprised ZnS activated with TbF_3. In both cases, the control layer 5 was black MnO_2 powder. The ZnS thin film/MnO_2 powder panels are extremely stable with respect to current control and brightness maintenance under pulsed DC excitation, at constant voltage operation.

Examples of these yellow emitting displays have been made which have exhibited, for example, in the first case, an almost constant brightness of 8 fL under 43V pulsed DC excitation of 10 μS pulses at 1% duty cycle for over 2400 hours operation at between 0.05 and 0.02% W/W efficiency, and in the second case 11 fL to over 3000 hours operation. The green emitting ZnS thin film/MnO_2, where the ZnS is activated with TbF_3 have produced a brightness of 3–4 fL after 2400 hours at 77V pulsed DC excitation.

The panel shown in Fig. 2 is identical to that shown in Fig. 1 (and like reference numbers have been used to indicate like parts) with the exception that the rear electrodes 6 have been omitted and the powder layer 5 has been formed into discrete ridges 7 separated by furrows or grooves 8. An electrical connection (not shown) is made to each of the ridges 7 of the powder layer 5.

The embodiment shown in Fig. 2 is intended for multiplex addressing and so transparent electrode film 2 is formed in strips running perpendicular to (or intersecting) the furrows 8.

CLAIMS

1. An electroluminescent phosphor panel suitable for both unidirectional and/or alternating voltage operations comprising in serial order, a transparent electrically insulating substrate, a transparent first electrode film, a first layer of insulating or semi-insulating, self-activated or activator-doped, phosphor and a second layer which is an electrically conducting or semi-conducting dark-coloured control layer.

2. A panel according to claim 1, wherein the powder of the second layer is elected from the group consisting of transition metal oxides, transition metal sulfides, rare earth metal oxides and rare earth metal sulfides.

3. A panel according to claim 1, wherein the powder of the second layer is selected from the metal chalcogenides.

4. A panel according to claim 3, wherein the powder of the second layer is selected from metal oxides.

5. A panel according to claim 3, wherein the powder of the second layer is selected from metal sulfides.

6. A panel according to claim 1, wherein the powder of the second layer is selected from the group consisting of PbS, PbO, CuO, MnO_2, Tb_4O_7, Eu_2O_3, PrO_2 and Ce_2S_3.

7. A panel according to claim 1, wherein the powder of the second layer is selected from the group consisting of non-emitting phosphor materials and non-activator-doped phosphor materials.

8. A panel according to claim 1, wherein the band gap of the control layer is less than 2 eV, preferably less than 1.8 eV.

9. A panel according to claim 1 which includes a second electrode in contact with the side of the second layer remote from the substrate.

10. A panel according to claim 1, which includes terminals in electrical contact with the second layer for supplying electrical power to said second layer, said second layer being electrically conductive.

11. A panel according to claim 10, wherein the second layer is composed of discrete ridges separated from each other by furrows.

12. A method of manufacture of a panel according to claim 1, comprising the steps of:

—depositing a transparent first electrode film onto a transparent insulating substrate;

—depositing a first layer of semi-insulating self-activated or activator-doped phosphor onto the first electrode film by thermal or electron beam evaporation techniques or by sputtering or by chemical deposition;

—spreading a second layer of an electrically conducting or semi-conducting dark-coloured powder selected from transition, rare earth or other metal compounds such as oxides, sulphides, or other chalcogenides, onto the first layer, and

—making electrical connections to said second layer.

13. A method as claimed in claim 12, which comprises forming the second layer into discrete ridges separated from each other by furrows.

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